I5 Conduction

Learn about:
- Thermal energy transfer in solids
- Conductors and insulators

Heat it up

Stephen's dad forgot to take the chicken out the freezer. Dinner is going to be very late unless they can quickly defrost the chicken. It has to be totally defrosted before they can cook it. They need to transfer thermal energy from the surroundings to the chicken.

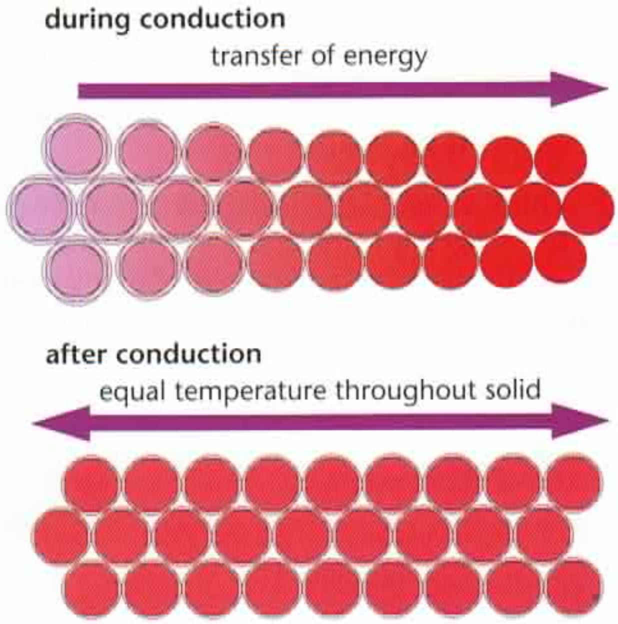
At first, the surroundings are much hotter than the chicken. Thermal energy is transferred from the surroundings to the chicken. The surroundings cool a little and the chicken heats up. Finally, everything ends up at the same temperature.

a **Explain why the surroundings only cool by a few degrees Celsius, while the chicken warms up by about 40 °C.**

Conduction in solids

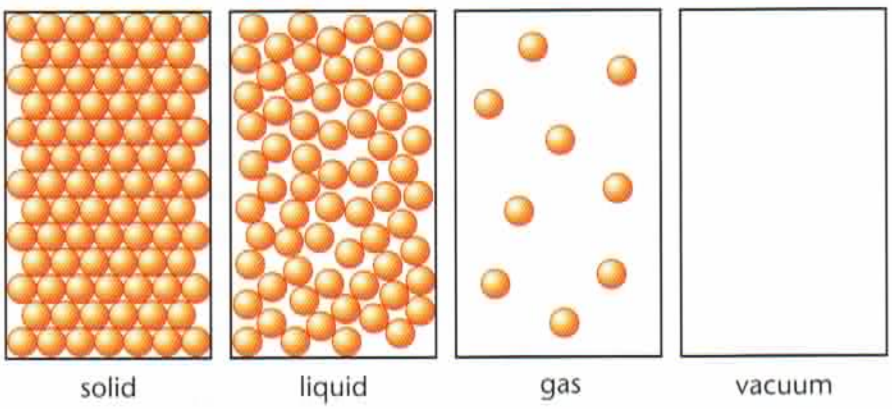
In solids, like the chicken, thermal energy is transferred from the hotter part to the cooler part by **conduction**. The thermal energy is passed from particle to particle without the particles moving from their places in the material.

Some of the particles in the chicken are shown in the diagram. The surface of the chicken is hotter than the rest of it. Where the temperature is higher, the particles have more energy and vibrate more. These particles hit against the neighbouring particles, making them vibrate more and thus increasing the temperature of that part of the solid.



The energy is passed from particle to particle through the chicken below, until all the particles are vibrating the same amount and the temperature is even throughout the material.

b **When does conduction stop and why?**



Conduction in non-solids

Look at the diagram on the left. Conduction works best in solids, where the particles are touching and each particle touches many neighbours. In liquids, the particles are touching, but each particle has fewer neighbours to hit against. Conduction is very poor in gases. This is because the particles are far apart in a gas and only hit each other occasionally.

There are some places where there are no particles at all. We call a place with no particles a **vacuum**. You can make a vacuum by pumping all the air out of a container. Much of outer space is a vacuum.

Obviously, conduction does not happen in a vacuum. There are no particles to hit each other, so there can be no transfer of thermal energy by conduction.

Thermal conductors and insulators

Think back to the frozen chicken. How can they reduce the time the chicken takes to heat up?

Some materials conduct thermal energy better than others. The stainless steel draining board, the aluminium foil and other metal objects are good **thermal conductors**. Other materials conduct thermal energy poorly. They are called **thermal insulators**. The cling film, the polystyrene tray and other plastics are thermal insulators.

Non-metal materials that contain gas pockets are very good thermal insulators. Expanded polystyrene, like the tray holding the chicken, is this type of material. So are fluffed-up feathers and woolly jumpers.

c Look at the bottom diagram on page 92.
(i) Choose a particle in the middle of the solid. How many other particles is it touching?
(ii) Repeat for the liquid, the gas and the vacuum.
(iii) Use your answers from *i* and *ii* to explain why solids conduct thermal energy best.

d Use you knowledge of conduction to explain why gas pockets make a material a very good insulator.

Questions

1 **a** Write down the following materials in order, with the best conductor first.

plastic **air** **graphite** **aluminium** **water**

b Explain how you decided on this order.
c Where would a vacuum be on this list? Give your reasons.

2 Use your ideas about particles to explain why kebabs cook more quickly on metal skewers than:

a with no skewers **b** on wooden skewers.

3 Look at this cartoon. It represents a solid with one end at a higher temperature than the other. The hands represent the particles and the money represents the energy. Draw or explain the next two frames in the cartoon, showing how energy is transferred during conduction.

One end of the solid is heated up.

For your notes:

- Thermal energy is transferred from hotter objects to cooler objects.
- **Conduction** is one of the ways in which thermal energy is transferred.
- In conduction, energy is transferred from one particle to the particles touching it, from hotter to colder particles.
- Solids are better conductors than liquids and gases. Some solids are better conductors than others.

16 Convection

Learn about:

- Thermal energy transfer in liquids and gases

Moving air

Think about a hot pie taken out of the oven and left to cool on a wire rack. It is surrounded by air, which is a poor conductor, but it still cools. The air moves, and the particles in the air carry the thermal energy away from the pie. Thermal energy transfer by moving particles is called **convection**. It happens in gases and liquids, because the particles in gases and liquids can move about.

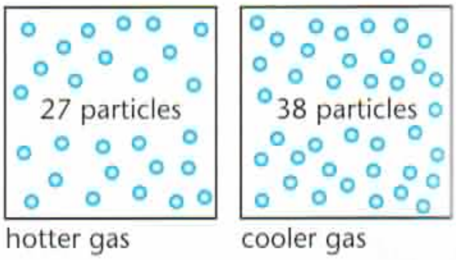
Look at the photo on the right. The candle is heating the air. The hot air then rises, causing the paper spiral to rotate. If you put your hand near the spiral, the air would feel very hot. Thermal energy has been transferred by convection.

a **Why does convection happen in gases and liquids but not in solids?**

Why does hot air rise?

When you heat air you give the particles more energy. They vibrate more and they move about more. The particles get further apart. The gas expands.

This means that there are fewer particles in the same volume. The diagram below shows the same volume of a hotter gas and a cooler gas. There are fewer particles in the hotter gas.



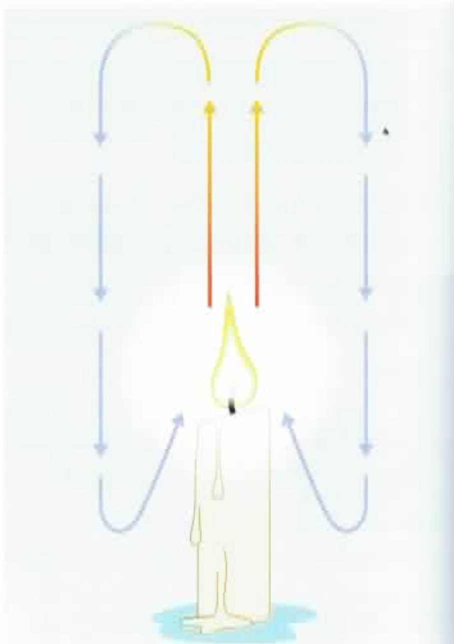
Fewer particles means less mass. The same volume of hotter gas weighs less than the same volume of cooler gas. It is less dense.

Less dense materials float compared to more dense materials. The hot air rises, like a cork bobbing up through water.

b **Look at the hot-air balloon on the left. Why is the air inside the balloon rising compared to the air outside the balloon?**

Convection currents

Think about the hot air above the candle. When the hot air rises, something has to take its place. Cooler air moves into the gap. This combination of hot air rising and cooler air falling is called a **convection current**. The diagram on the right shows the convection current around the candle. The convection current mixes the air. Eventually all the air will be heated. When all the air is the same temperature, the convection current will stop.



Convection in liquids

Convection also happens in liquids. Look at the photos on the right. They show the same beaker of water being heated. The flame of the Bunsen burner is pointing at the left of the beaker, so only the water there is being heated. Purple dye has been added so that you can see the movement of the water. The photo on the left shows the water after it has been heated for one minute. The photo on the far right was taken after two minutes of heating.

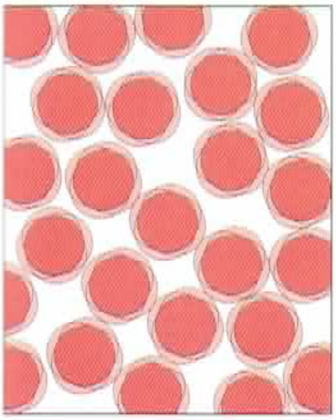
one minute

two minutes

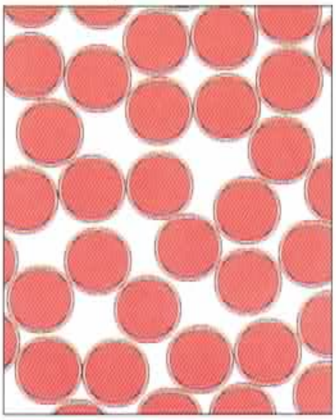
The hot water rises. This can be seen by the purple dye rising. There is a convection current in the water in the beaker. Again, thermal energy is being transferred through the liquid by convection.

c What would have happened to the purple dye by three minutes?

hotter liquid



colder liquid



Why do hotter liquids rise?

When you heat a liquid, the particles vibrate more. Each particle takes up more space, so the liquid expands. The diagram on the left shows the same volume of a hotter liquid and a cooler liquid.

d Compare the number of particles in the same volume of the hotter liquid and the cooler liquid.

The hotter liquid has fewer particles in the same volume and is therefore less dense than the cooler liquid. It will rise, in the same way that hot gases rise.

Questions

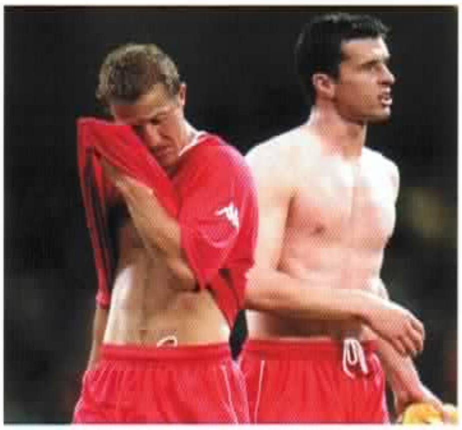
1. If the air in a hot-air balloon is allowed to cool, the balloon falls. Explain why.
2. During a hot summer's day, the sea is cooler than the land, so the air above the sea is cooler than the air above the land. Explain, using a labelled diagram, how this leads to a cooling breeze blowing in from the sea.
3. Write an explanation of how a heater on one side of a room can heat the air in the whole room.
4. Describe a 'children and money' model for convection. Remember that the children represent the particles and the money represents the energy. (*Hint:* think how particles move in a liquid and in a gas.)

For your notes:

- In **convection** the particles move, transferring the thermal energy.
- Convection happens in gases and liquids, but not in solids.
- A **convection current** happens when one part of a gas or liquid is hotter than another part.

I7 Evaporation, radiation

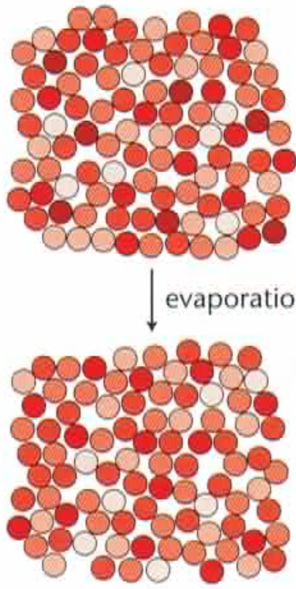
Suddenly cooler



You cool down very quickly if you stand around while you are wet. This cooling is because water is **evaporating** from our skin.

We also cool down by evaporation when we sweat. Our sweat glands push water out of our pores onto the skin. The water then evaporates from the skin, transferring away thermal energy and cooling our bodies.

Energetic particles

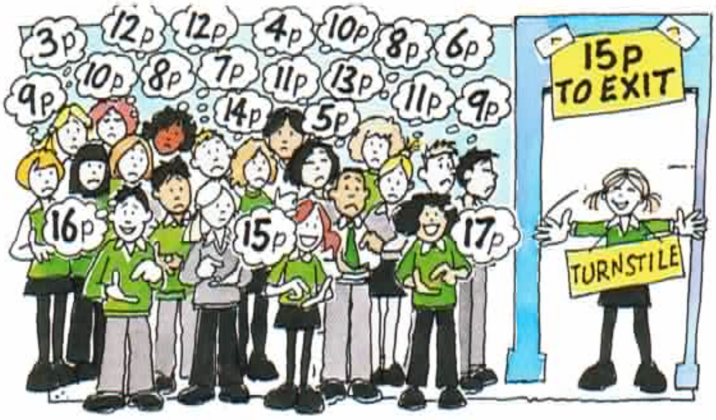


To understand why evaporation causes cooling, you have to think about the particles in the liquid. When you look at the particles in the liquid more closely, you realise that some have more kinetic energy and some have less.

This is shown in the diagram on the right. The darker the red, the more kinetic energy the particle is carrying. The particles with the most energy are the ones that leave the liquid when they reach the surface.

The temperature of the liquid falls. This is because temperature depends on the average energy per particle. If the particles with the most energy leave, there is less energy to be shared between the particles that are left and the temperature of the liquid falls.

You can use the 'children with money' model of energy transfer to think about cooling by evaporation.



There is 200p in the room, split between 20 children. Only three children have the money they need to leave the room. The average money per child is 10p.

There is 152p in the room, split between 17 children. The average money per child is 8.9p.

a **In this model, what represents:**
(i) the energy? **(ii) the particles?**
(iii) the temperature? **(iv) the process of evaporation?**

Radiation

Thermal energy can be transferred without using particles. This is a good thing, as there is only empty space, a vacuum, between the Sun and us. Thermal energy from the Sun is transferred to the Earth by a process called **radiation**. Radiation is the transfer of thermal energy without particles. During radiation, **infrared radiation** carries thermal energy from a hotter object to a cooler object.

Infrared radiation is like light in many ways. The infrared radiation is produced by a source. It travels away from the source in all directions. All hot objects are a source of infrared radiation. The photo on the right was taken with an infrared camera, which detects infrared radiation rather than light. The people show up brightly, because they are sources of infrared radiation.

b **The Earth is not heated by conduction or convection.**
(i) Why not?
(ii) What type of thermal energy transfer heats the Earth?

The Sun produces infrared radiation that heats the Earth. The radiation can travel across the emptiness of space because, like light, it does not need a material to travel through.

Like light, infrared radiation can be reflected by smooth, shiny surfaces. We use this to help stop energy loss from our bodies and our homes. Look at the photo on the left. The shiny survival blanket keeps the athlete warm, reflecting the infrared radiation back towards her body.

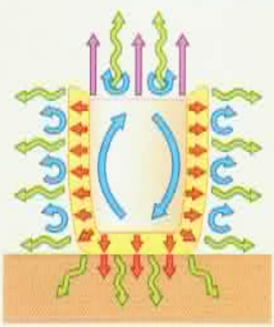
c **Ellen is trying to apply the 'children with money' model of energy transfer to radiation. She decides on children with coins standing on one side of a room, throwing coins to children standing on the other side of the room.**
(i) Why doesn't Ellen have any children in the middle of the room?
(ii) What represents the hot object, the cooler object and the infrared radiation?

Questions

1 Explain carefully how sweating cools the skin using the words below.

evaporation **particles** **energy** **temperature**

2 Look at this diagram of the cup of tea losing thermal energy to its surroundings. Identify the method of energy transfer shown by each coloured arrow.



3 Use the 'children and money' model to compare conduction, convection and radiation.

For your notes:

- Thermal energy can be transferred from a liquid by **evaporation**. The liquid then cools its surroundings.
- **Radiation** happens when thermal energy is transferred by **infrared radiation**, which is like light.